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Dry Cask Storage Verification with Muon Radiography

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Spent Fuel in Dry Cask Storage

- Increasing amounts of spent fuel are being placed in dry casks for long term storage
- This fuel presents a potential proliferation risk if diverted for plutonium reprocessing

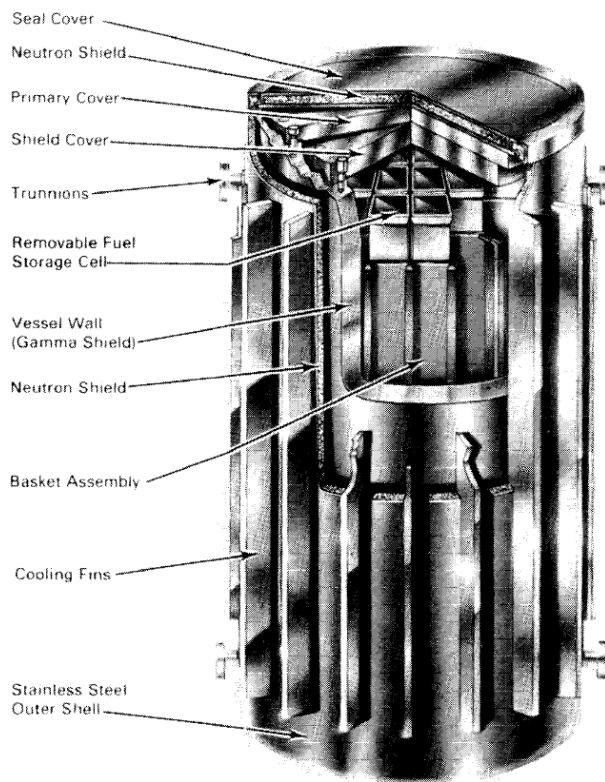
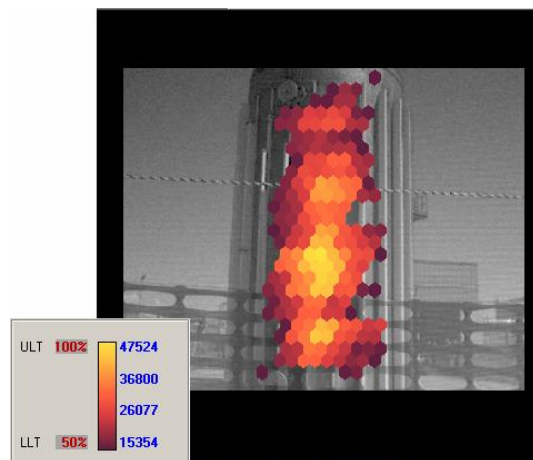
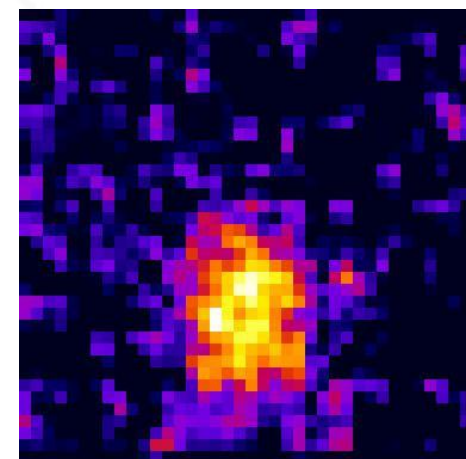


Figure S-1. MC-10 Spent Fuel Storage Cask

The cask's heavy shielding precludes detailed radiographic inspection by typical probes



Gamma ray image



Neutron image

Ziock et al, *IEEE Nuclear Science Symposium Conference Record*, vol.2, no., pp.1163,1167, 23-29 Oct. 2005

Currently, the only viable method of verification is opening cask for visual inspection.
-Costly, invasive, time-consuming, potentially dangerous

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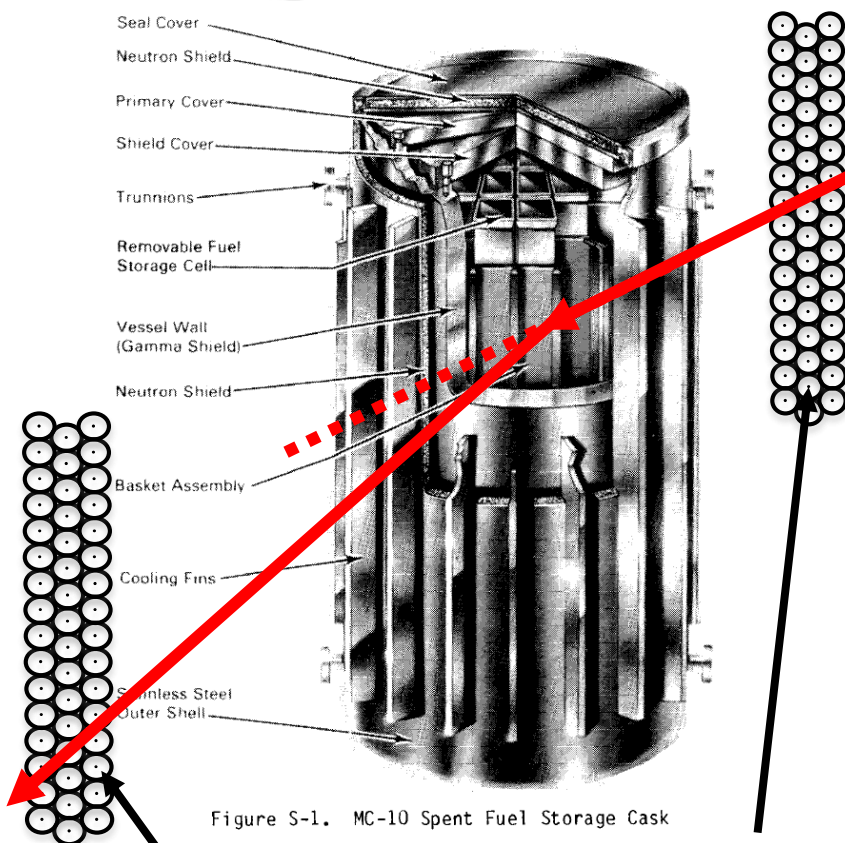


Figure S-1. MC-10 Spent Fuel Storage Cask

A new technique: muon multiple scattering radiography

- Cosmic ray muons impinge on the Earth at a rate of $\sim 1/\text{cm}^2$ per minute
- Capable of penetrating through many meters of steel/lead/concrete shielding
- Scattering angle is dependent on Z of material muon passes through

Layers of drift tubes record muon position and trajectories before and after passing through cask

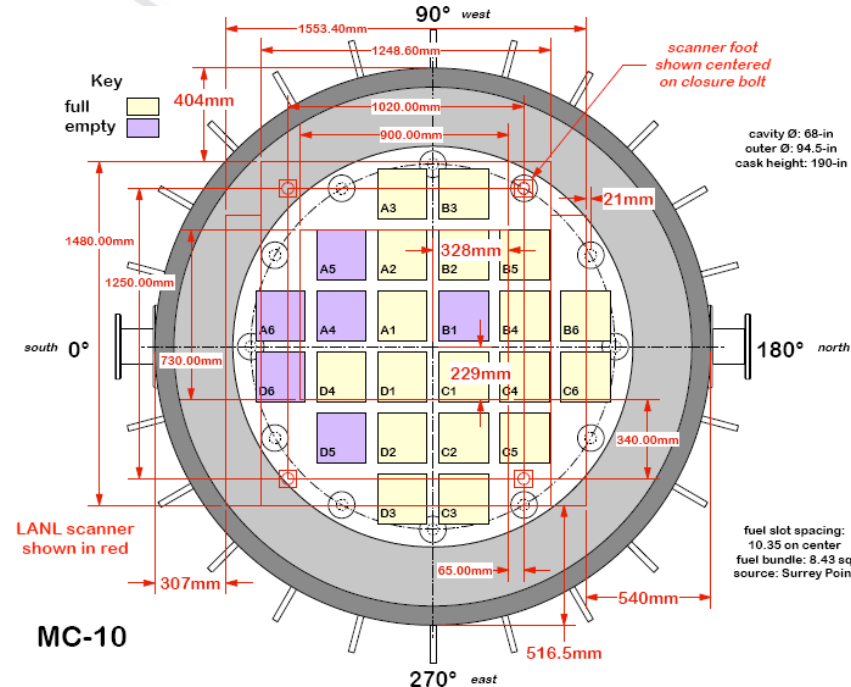
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Measurement Setup at INL

Muon trackers in weatherproof enclosures.
One side elevated to increase muon flux
through both detectors (falls off as $\sim \cos^2 \Theta$).



Westinghouse MC-10 cask

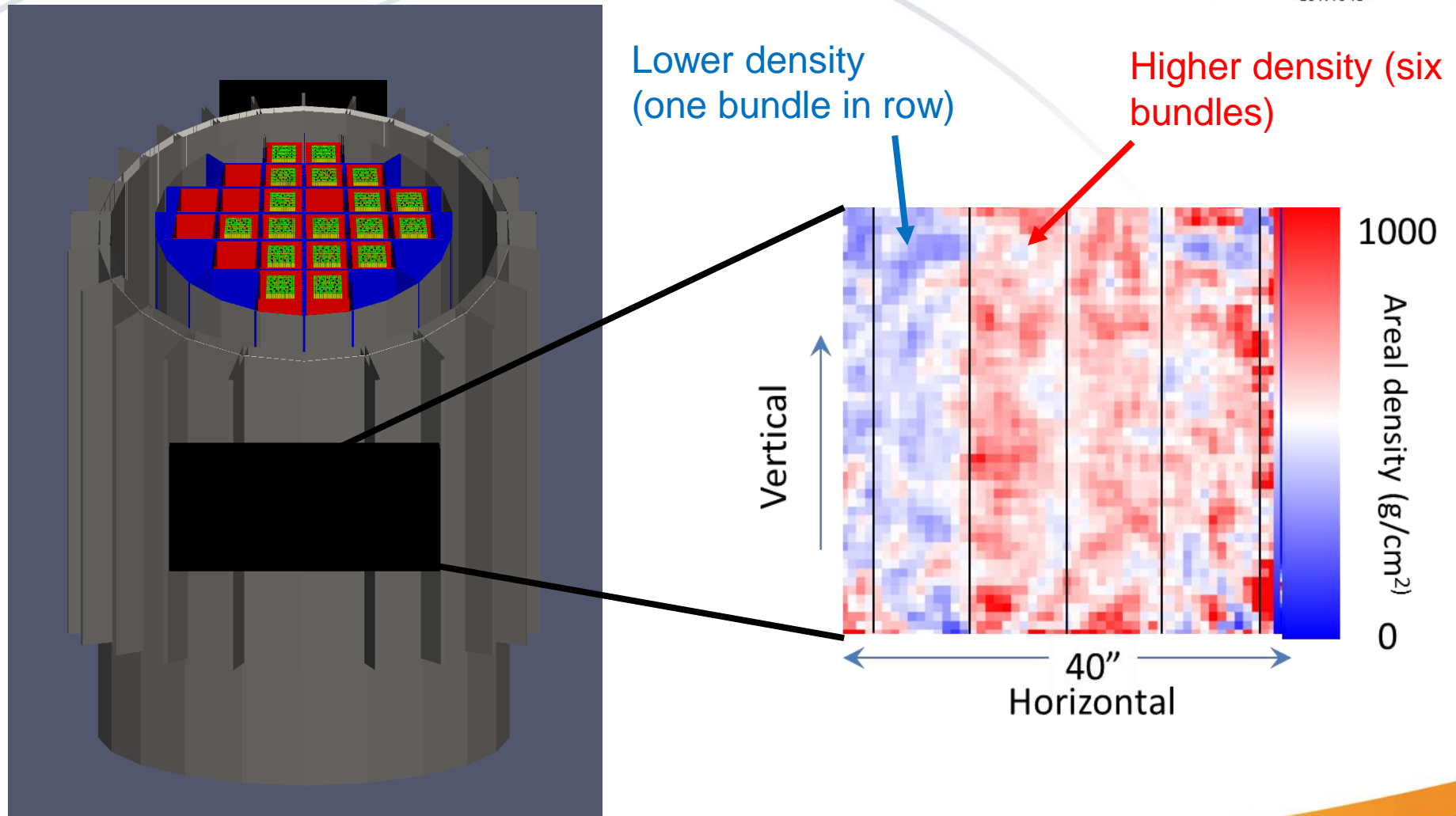


Cask loading profile. Several fuel bundles are missing. The bundles are high-burnup PWR fuel, removed from commercial plants in early 80s.

Count time: 100 hrs

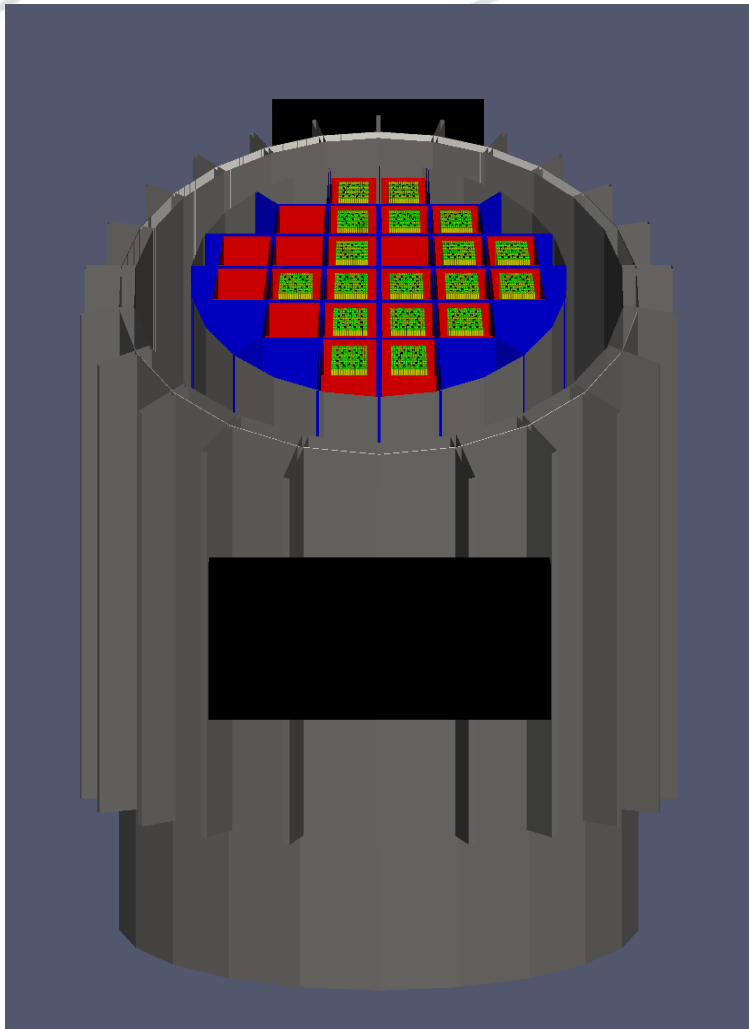
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Preliminary Results

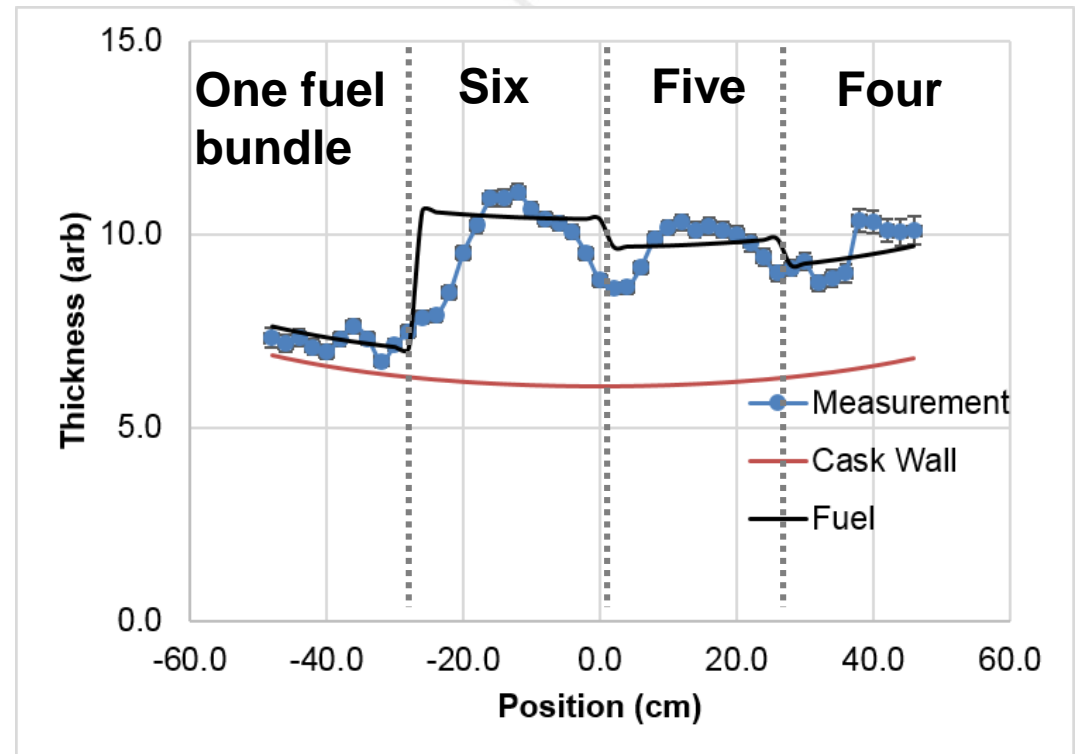


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Preliminary Results



Integrated Thickness



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Summary

- Cosmic ray muons can penetrate significant shielding that defeats typical radiographic probes.
- Preliminary results on identifying partial defects in dry cask contents are promising.
- Further modeling and data analysis are underway.

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BACKUPS

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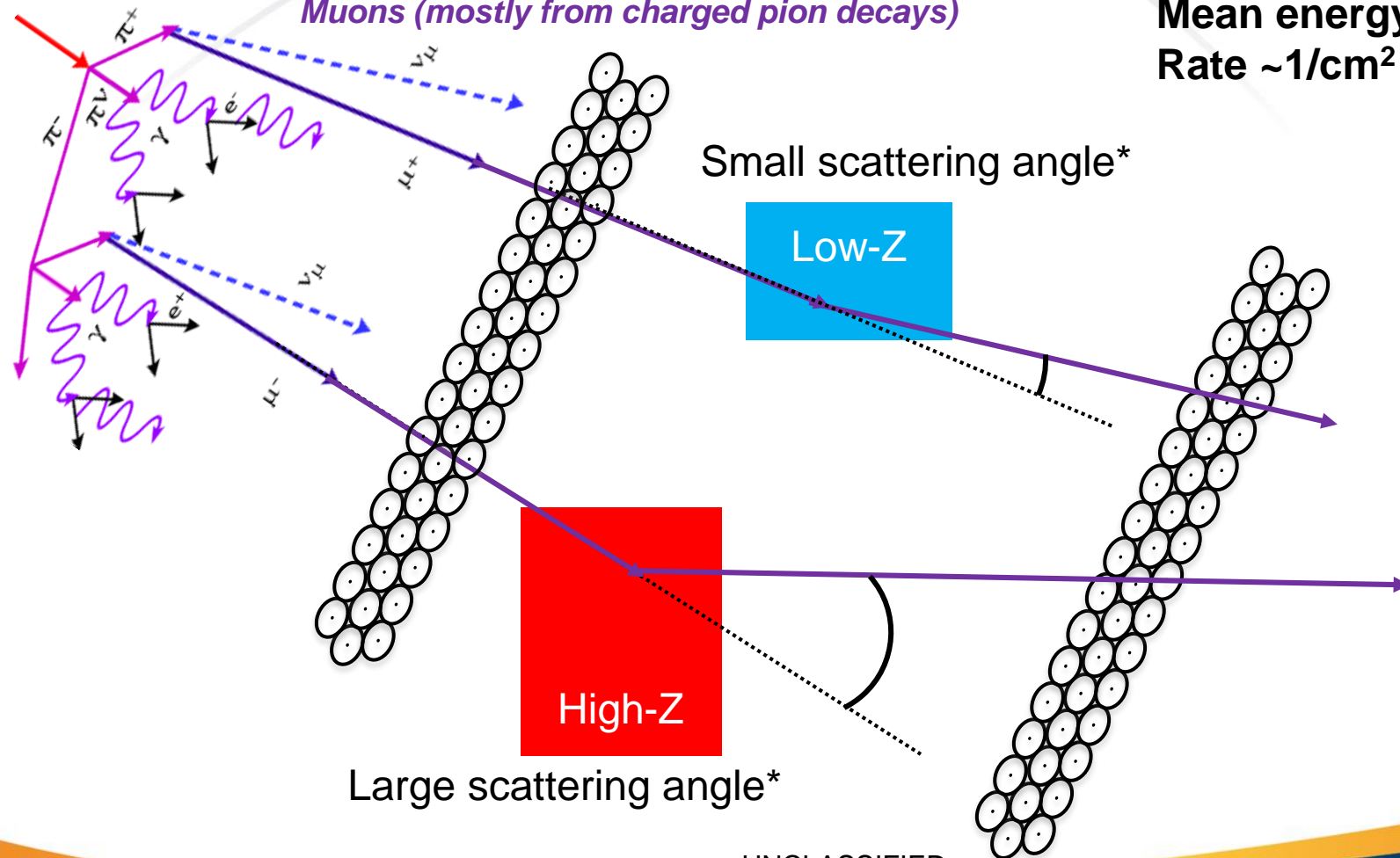
Muon Radiography – Imaging with Natural Cosmic Radiation

High-energy primary cosmic ray

Short-lived secondary particles (mostly pions)

Muons (mostly from charged pion decays)

Muon mass $\sim 200 m_{\text{electron}}$
Mean energy $\sim 3 \text{ GeV}$
Rate $\sim 1/\text{cm}^2$ per minute



*angles greatly exaggerated

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